EXPERIMENTAL AND ANALYTICAL EVALUATION OF BENDING FOR ALUMINUM

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ABSTRACT

Spring-back is a common phenomenon that occurs in sheet metal bending after unloading the tooling or punch due to material elastic recovery. Three different thicknesses, 1, 2 and 3 mm are selected and 0^o, 45^o and 90^o of orientation are chosen as the considered parameters while the 30^o is selected as reference bending angle. In this research, it studies about determining the spring-back angle by using experimental and analytical method. Different equations are use where the Daw-Kwei Leu equation as the first equation is considers the thickness poisson ratio and strain hardening exponent while the Dongye Fei and Peter Hodgson equation is only consider the thickness effect, poisson ratio and die width for spring-back. Experiment for bending is limited in bottoming v-die bending. Data from the tensile test are used in determining the spring-back value for analytical method while press brake machine is a tool to complete the test. As the finding of the research, increasing the sheet thickness is decrease the spring-back value for analytical and experiment. In experiment, 1 mm and 2 mm gain a decreasing spring-back value related with analytical and previous study, but 3 mm of thickness has a spring-go appearance where the outer layer of outer diameter is happened a crack and this is proved the result where the material already exceed the elastic region for the aluminum.

ABSTRAK

Spring-back merupakan fenomena yang biasa terjadi semasa proses pembengkokan dimana bahan tersebut akan cuba kembali ke bentuk asal seperti sebelumnya. Berdasarkan kajian ini, ianya melibatkan pengkajian mengenai *spring-back* dengan menggunakan dua cara, eksperimen dan analisis. Tiga ketebalan yang berbeza, 1, 2, dan 3 mm telah dipilih manakala tiga arah orientasi 0^o, 45^o dan 90^o dipilih sebagai parameter utama. 30^o merupakan darjah pembengkokan yang menjadi rujukan kepada analisis dan juga eksperimen. Di dalam analisis, ianya melibatkan dua penggunaan rumus berbeza. Pertama, rumus Daw-Kwei Lue mengambil kira pengaruh ketebalan bahan dan juga exponen pengerasan terikan manakala rumus Dongye Fei dan Peter Hodgson hanya mengambil kira pengaruh ketebalan bahan dan kelebaran acuan. Acuan-v telah dipilih untuk digunakan bagi melengkapkan eksperimen. Data-data yang diperoleh daripada ujian tegangan akan digunakan untuk melengkapkan proses analisis manakala mesin tekan merupakan peralatan utama untuk melengkapkan eksperimen ini. Penemuan di dalam analisis mendapati bahawa meningkatkan ketebalan bahan akan mengurangkan nilai *spring-back* tetapi, melalui eksperimen, hanya keputusan daripada 1 dan 2 mm sahaja yang menyamai keputusan analisis dan kajian-kajian sebelum ini. Ketebalan 3 mm menghasilkan keputusan yang berlainan dimana *spring-go* terjadi dan ianya disokong melalui keadaan bahan dimana rekahan telah berlaku di lapisan luar pembengkokan. Hal ini disebabkan kerana bahan telah melebihi tahap lenturan aluminium dan tidak mampu untuk kembali ke bentuk asal.

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LIST OF SYMBOLS

L_b	=	Bend Allowance
a	=	Bend Angle
R	=	Bend Radius
k	=	Constant
P_v	=	Bending Force
C	=	Coefficient
B	=	Sheet Metal Width
T/t	=	Sheet Metal Thickness
σ_b	=	Material tensile Strength
w	=	Die Gap
R	=	Anisotropy Value
R_0	=	Anisotropy Value for 0^o
R_{45}	=	Anisotropy Value for 45^o
R_{90}	=	Anisotropy Value for 90^o
r_o	=	Outer Radius
r_i	=	Inner Radius
ρ	=	Neutral Axis
$\Delta\theta$	=	Spring-back Angle
θ	=	Bending Angle

UTS	=	Ultimate Tensile Strength
n	=	Strain Hardening Exponent
E	=	Young Modulus
v	=	Poisson Ratio
e	=	Exponent

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter explains clearly about project background, problem statement, project objective and scope of the project.

1.2 Project Background

Sheet metal is popular in industries. There have many applications using sheet metal such as ductwork, airplane wings, car bodies, medical tables and storage units, building facades, steel sheets, tubing and signs. Sheet metals come in flat pieces or coils and are measured by their thickness or gauge. Very thin pieces of metal are called foil or leaf and thick metals are called plate. Some of the industries using bending machine as their process to produce their product.

This project is about experimental and analytical evaluation of bending for aluminum sheet metal. In this project, 1, 2, and 3 mm thickness of aluminum are selected. Aluminum is selected since it has the light-weight characteristic. Also, aluminum is common usage in industries. For the purpose, tensile test is performed to acquire material data as input to the analytical evaluation. The tensile test is conducted by using a tensile test machine to gain the stress strain data of aluminum. Before that, tensile test specimens are creating by using a CNC milling machine.

Bending test is done by using press brake machine. In this test, bottoming v-die bending is selected since there has many types of die in bending process. 30 degree of die angle is functioning as a reference angle and this project only considers the different thicknesses and rolling directions.

In analyzing the results of an experiment, computer scanner and SOLIDWORK software are used in determining the specimen angle. The angle for each specimen will be deducted by the reference angle in determining the spring-back value. Finally, the results for every thicknesses and orientations are compared.

1.3 Problem Statement

While the sheet metal induct into the bending process, spring back appears where the materials are not in the exact position or it tries to return back to its original position. Usually this phenomenon happens when the die is removed from the material after the bending process. This spring back happens because of the material characteristic that should be considered. Because of this spring back, most of companies in the industry have a problem to control their output product quality. Also, this will cause problems in die making or designing process and this will increase their cost just to reduce the spring back and control their product quality.

1.4 Project Objectives

The objectives for this project are:

i. To determine the reliability of analytical method in sheet metal bending of aluminum.
ii. To determine the influence of thickness and anisotropy in spring-back.

1.5 Scopes of Project

Scopes of project are limited to:

i. To conduct tensile test to collect the data of material properties.
ii. To conduct the V - bending experiment by using press brake machine.
iii. To evaluate the analytical result.
iv. To compare the result between analytical and experiment.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In conducting a research, review is an important section to be familiar with the area of study. In this chapter, it will explain about sheet metal forming, sheet metal bending, type of bending, spring-back, and analytical method. Also, some of previous study is revealed in this chapter.

2.2 Sheet Metal Forming

Sheet metal parts are light weight and can have versatile shape due to its low cost and generally good strength and formability characteristics. Thus, low-carbon steel is the most common used sheet metal (Bruce et al., 2004).

Many sheet metal forming processes are used to produce parts and shapes. Usually, there is more than one method of manufacturing to form the sheet metal. The broad categories of processing methods for materials are as follows:

i. Roll forming: Long parts with constant complex cross-section.
ii. Stretch forming: Large parts with shallow contours that is suitable for low quantity production.
iii. Drawing: Shallow or deep parts with relatively simple shapes for high production rates.

iv. Stamping: Includes punching, blanking, embossing, bending, flanging, and coining.
v. Spinning: Small or large axisymmetric parts with good surface finish and low cost tooling (Kalpakjian and Schmid. 2001).

2.3 Sheet Metal Bending

Sheet metal bending imparts stiffness to the part by increasing its moment of inertia. For example, the flanges, beads, and seams increase the stiffness of structure without adding any weight. Figure 2.1 below show the terminology of bending. (Guidice et al., 2006)

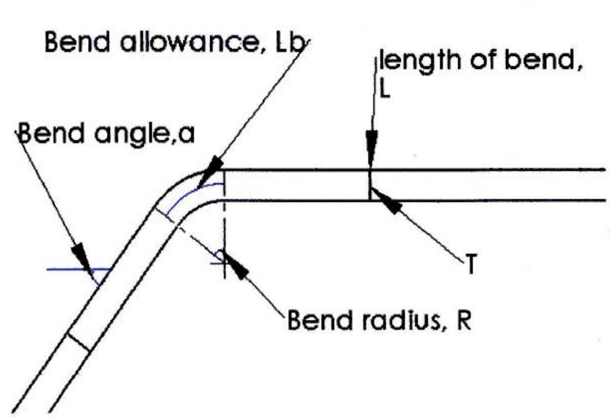


Figure 2.1: Bending terminology

Source: Guidice et.al., 2006

The bend allowance, $\boldsymbol{L_b}$ is length of the neutral axis in bend. The position of L_b will be depends on the radius since the formula of bending angle is:

$$L_b = a(R + k) \tag{1}$$

Where a is bend angle, ^{o}. T is sheet thickness, mm. R is bend radius, mm and k is constant.

In addition, bending is a process by which metal can be deformed by plastically deforming the material and changing its shape. The material is stressed beyond the yield strength but below the ultimate tensile strength. The surface area of the material does not change much. Bending usually refers to deformation about one axis. Bending is a flexible process by which many different shapes can be produced (Olaf D., July 2002).

Bending process is about shaping material without removing any chips around a definite axis through or without heat. Bending is a process of placing a sheet metal over the matrix on the press bed where the sheet metal will follow the die shape and punch tips since entering the die after the punch press it into the die (Ozgur T. et al., 2007).

2.4 Type of Bending

There has many type of bending in sheet metal forming. This project only considers v-die and bottoming bending.

2.4.1 V-Die Bending

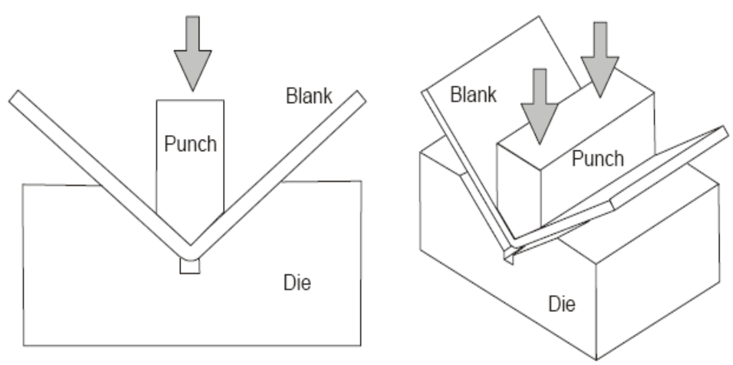


Figure 2.2: V-die bending

Source: Olaf D., July 2002

Figure 2.2 shows the V-die bending. Sheet metal will bend between the punch and die shaping in v shape. There has 3 types of die, bottoming, air or coining. Compare with the U-die bending where the only appear is spring-back, the spring-go and spring-back can be determined using the V-die bending.

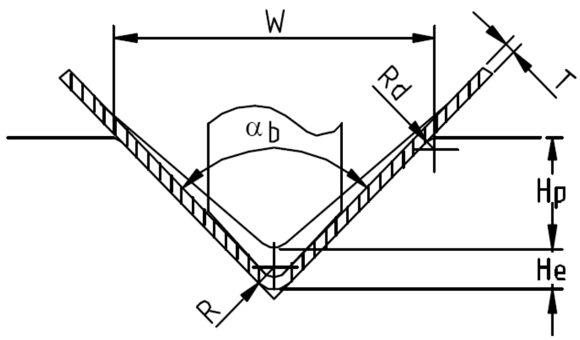


Figure 2.3: Die setup and bending parameter

Source: Ozgur T. et al., 2007

Figure 2.3 shows the setup of die and punch for v-bending process. Before the V-bending test, force for the V-bending machine should can be calculate to avoid the over force while bending test. This calculation method can be use as a guide and also can avoid the die or the specimen of bending process broken if the over press on the specimen or die. The calculation of bending force can be determined by:

Bending Force:

$$P_v = C \times \frac{B \times T^2 \times \sigma_b}{w} \times 10 \tag{2}$$

Coefficient:

$$C = 1 \times \frac{4 \times T}{w} \tag{3}$$

2.4.2 Bottoming

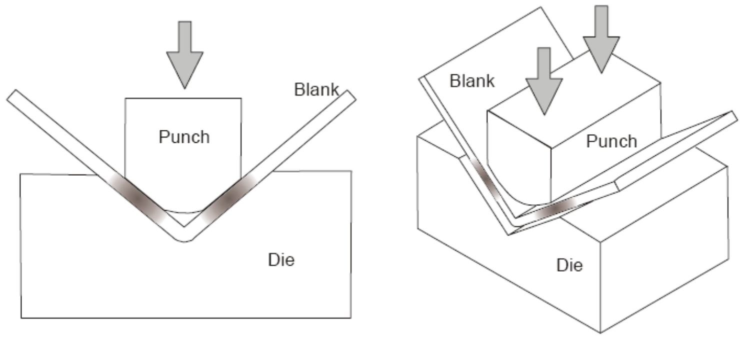


Figure 2.4: Bottoming bending

Source: Olaf D., 2002

Figure 2.4 is a bottoming bending. It has a similarity to both air bending and coining. In this process, the die angle should match the intended angle of the work piece, adjusting a few degrees for spring back, hence the existence of 88 degree tooling to achieve 90 degree angles. The workpiece is first bottomed against the die, then the radius of the punch is forced into the work piece which achieves the angle of the punch, it is then released and the workpiece springs back to meet the die again (Olaf D., 2002).

Unlike coining, however the material is not under so much tonnage that the metal flows. Because of this there is still spring back which must be compensated for. In order to do compensate the angle of the punch can be smaller than the angle of the die by a few degrees allowing an over-bend when the punch tip is forced into the workpiece, it should not be larger or else it will damage the tooling (Olaf D., 2002).

2.5 Spring-back

Sheet metal bending also depends on the spring back effect. All material has their modulus of elasticity and spring back is caused by the redistribution of stress in sheet material after the tooling is removed. (Zhang et al., 2006)

When releasing the load, the material will try to recover back into its initial form and the material bend expands backward with some amount of stretching. This behavior already called as ‘spring-back’ (Ozgur T. et al., 2007).

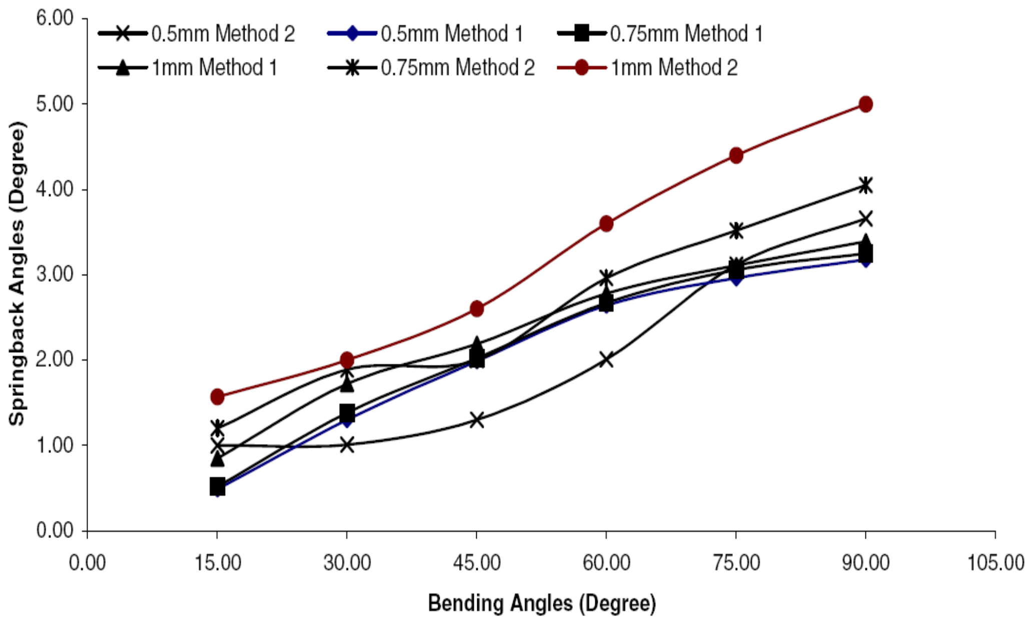


Figure 2.5: A combined presentation of the spring-back graph from first and second method.

Source: Ozgur T. et al., 2007

Figure 2.5 above is a result from (Ozgur Tekaslan et.al., 2007) where there are studying about spring-back of stainless steel sheet metal in V-die bending. Two different methods are used in their research where the first method, the punch is held about 20 second and the second method, the punch is not held but will return after the bending process is complete. From the graph above, it has determined that increasing the thickness of sheet metal will increase the spring-back.

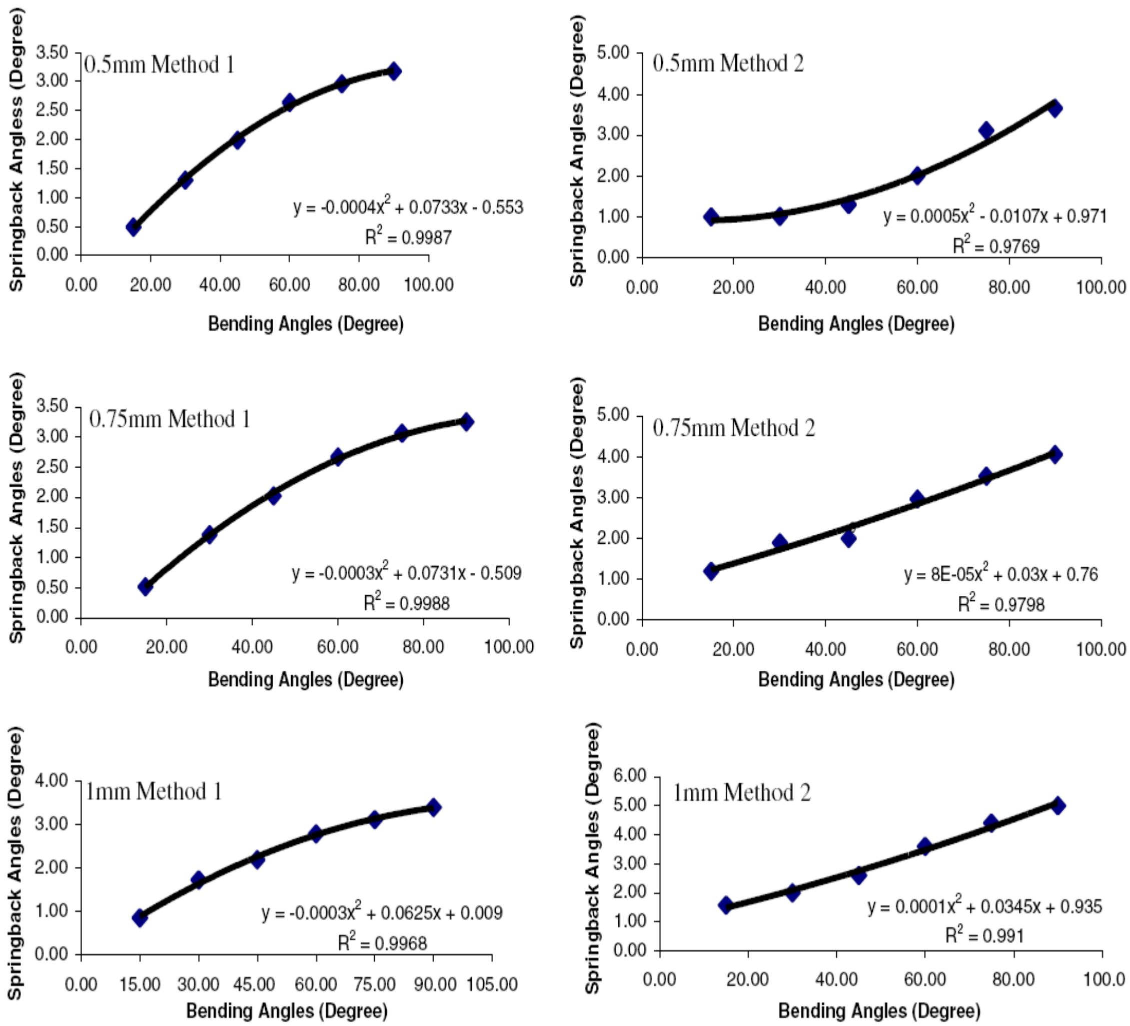
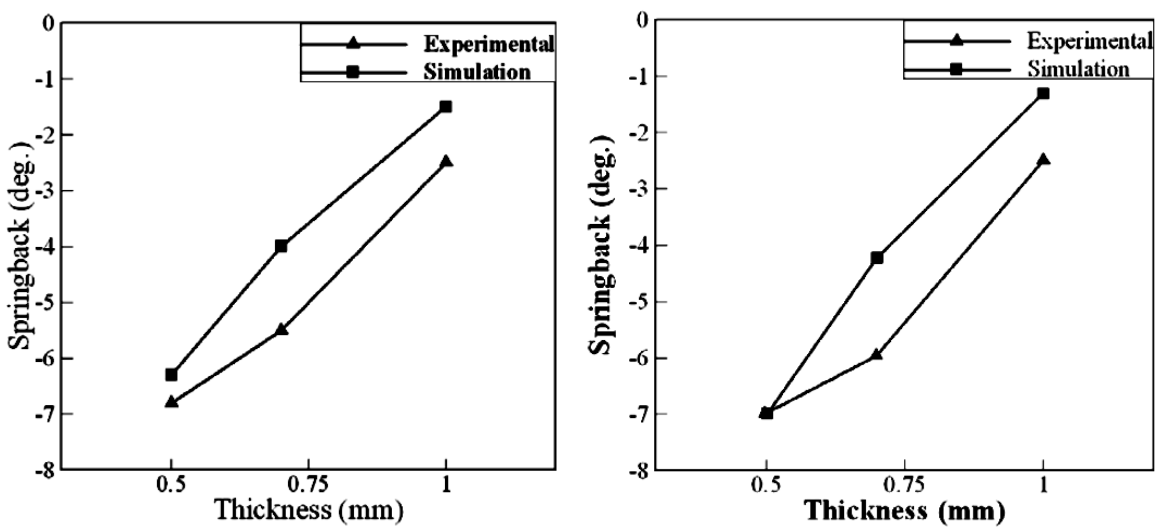


Figure 2.6: Spring-back graphs and polynomial curve.

Source: Ozgur T. et al., 2007

The different bending angles also give an effect to spring-back. Compare with the Figure 2.6, changing the bending angle is more effective to increasing the spring-back compare with increasing the sheet metal thickness.

Bakshi M.J. et al., (2009) has studied about spring-back of CK67 steel sheet in V-die and U-die bending process where they are compare the experimental and finite element method. In their study, there are included the orientation of rolling for the sheet metal where 0^o, 45^o, and 90^o are consider. The sheet thicknesses about 0.5, 0.7 and 1 mm were examined. Also, 2, 4, and 6 mm of punch radius are use to determine either the different punch radius effecting the spring-back.



a) Orientation 0^o b) Orientation 45^o

Figure 2.7: Effect of the sheet thickness between different orientations

Source: Bakhshi M.J. et al., 2009